Measurement of the Cosmic Background radiation.

In this experiment we use a very sensitive microwave receiver which operates at a wavelength of about 1 cm, about 10 times shorter than the wavelengths used by satellite receivers for Direct TV. The radiation is collected in a horn and the signals amplified by a very low noise amplifier located directly behind the horn. Since we are measuring a very low signal the amplifier has to be cooled to within a few degrees of absolute zero and this is done by using a refrigerator, similar in many respects to domestic refrigerators but using helium that is liquefied and recycled. Even so the noise temperature of the receiver is much larger than the signal and one of the most important parts of the experiment is to determine the exact noise of the receiver. The other problem is that the air itself gives out radiation and we need some way of taking out the effect of the earth's atmosphere.

Measuring the Noise of the Receiver

The noise of the receiver is measured as a temperature, which is the temperature that a black body would have if it gave the same noise at the operating wavelength. The important thing is that the noise signal is directly proportional to temperature. If we can put two sources of known temperature, one much colder than the other we can estimate the noise temperature of the receiver. We therefore put a piece of plastic treated to act as a black body at room temperature in front of the horn and measure the signal the receiver picks up from this source as well as its temperature. We then plunged a copper cone into liquid nitrogen (temperature 77 ^{0} K) and measured the signal at this level. If we draw a graph of temperature against signal with these points plotted we can extrapolate to see what the noise would be if the source temperature of the copper cone could be taken to absolute zero. In this case there would be no signal and all the measured signal is due to the receiver itself.

Taking out the effect of the earth's atmosphere

Astronomers have used measurements of the brightness of a star as a function of AIR MASS to make correction for the effect of the earth's atmosphere. The earth's atmosphere is not a black body because most of the radiation at 1 cm passes through the atmosphere without absorption. However the temperature of the atmosphere is about 250 ^{0}K and so even a little energy from the atmosphere swamps the cosmic background signal. The amount of signal from the atmosphere depends on the amount of air between us and the cosmic background. If the atmosphere is plane parallel (which is a good approximation (Why?) then the amount of air (air mass) depends on the Secant of the distance the telescope points from the Zenith. At the zenith Sec z =1 and the air mass is therefore 1x constant. AT an angle of 60^0 from the zenith Sec Z is 2.0. If you plot the signal measured of the sky (which is the cosmic + atmosphere+ receiver noise) against Zenith angle you find that the signal, increases with increasing zenith angle. You can therefore plot the signal as a function of the air mass, which goes from an air mass of 1 (at the Zenith) to 2 at 60 ^{0}. If you extrapolate the measurements to zer0 air mass you can determine what the signal would have been outside the earth's atmosphere! You may want to discuss this with your TA.

Working out the Background noise temperature

You recorded signals looking at the sky (cosmic noise+ atmosphere+ receiver noise) and at two black body sources (black body noise+ receiver noise) at a number of different zenith angles. For each observation at a different zenith angle you should estimate the receiver noise temperature and the sky noise (which is the cosmic background signal atmosphere) By plotting this signal as a function of air mass you can measure the temperature of the cosmic background. Discuss.